

# The Inca collection (13th-15th century AD) from the Boccolari-Parenti collection (Modena, Italy): Preliminary bioanthropological and paleopathological analyses

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**Abstract.** The section on Ancient Peru of the Civic Museum of Modena preserves a valuable collection of materials recovered by Antonio Boccolari and Paolo Parenti, two officers of the Italian navy who were part of the crew of the Corvetta Vettor Pisani, during his voyage of circumnavigation of the globe, towards the end of the 19th century. In the collection, there is an intact mummy and several heads from the Necropolis of Ancón, which can be traced back to a cultural horizon between the 11th century AD and the final period of the Inca Empire (1532). The mummy was subjected to direct inspection, a CT scan was performed at the Polyclinico of Modena then several skulls were taken for histological investigations, FTIR spectroscopic studies, radiocarbon dating and genetic study. CT dataset was also used for virtual facial reconstruction. The analysis of the biological profile indicates the sex of the mummy as female, with an age at death of 17-20 years, large skin folds suggest the presence of body fat. The anthropometric evaluation demonstrates a good bone consistency, without indices of strength, the skull has received an anthropogenic modification. The CT scan shows a part of the trachea and esophagus, a large part of the diaphragm, probably the two kidneys, plus different vascular structures are still visible. CT scan also revealed teeth spread throughout the body of the mummy. Numerous cotton seeds were found in the abdomen, probably the result of a rodent burrow. Considering the level of skeletonization reached by the seven skulls and the single calvarium, the investigation applied was the direct analysis. Interesting is the presence of auricular exostosis in a male individual (Id. 4), a condition that develops mainly due to environmental factors; in the case of ancient populations, as in our case study, the presence of this character is probably attributable to the action of spearfishing. The cranial indicators obtained reveal a general brachycephalic index (a skull with a decreased antero-posterior diameter). Additionally, in the case of Id. 1, 5, 6, and the mummified girl, a hyperbrachycephalic index is observed.

**Key words:** paleopathology; Inca mummy; bioanthropological collection

## Introduction

The collection of partly skeletonized and mummified remains belonging to the Boccolari-Parenti collection, preserved within the Ethnological Collections

of the Civic Museum of Modena (Italy), on the exhibition “People of Ancon” scheduled for late 2024, has benefited from a careful bioanthropological reanalysis conducted using the most modern diagnostic and analytical techniques available. This anthropological

sample, which is linked to the ancient coastal population of the region, was selected and collected from the necropolis of origin at the end of the 1800s, with the aim of finding out and showing “amazing” aspects of distant populations, without particular ethical approaches that nowadays regulate this type of remains. The necropolis is located along the Peruvian Central Coast about 42 km north of Lima, where the modern namesake seaside resort was built in the second half of the last century. The necropolis is spatially located in a flat, pre-hilly area, whose boundaries are traced to the west by the Pacific Ocean; to the north by the Pasamayo dunes with their significant altitude, with which they divide it from the Chancay valley; to the east by the foothills of the Andes and to the south by a promontory called Cabo Mulatos, which separates it from the Chillón valley.

## Material and Methods

The direct investigation carried out on the anthropological elements displayed in the exhibition, considered some peculiarities of the sample under analysis, which represent an image, albeit faded, of a peculiar ancient population. The classical anthropological analysis was concerned with reconstructing the biological profile of the subjects under study through the investigations relating to the identification of sex (Buikstra & Ubelaker, 1994; Bruzek, 2002; Acsadi & Nemeskeri, 1970), age at death (Meindl & Lovejoy, 1985; Martin & Saller, 1957; Lovejoy, 1985; Brothwell, 1989), when possible to anthropometric characteristics such as height, the identification of body indexes (Martin & Saller, 1957; Pearson, 1899; Trotter & Gleser, 1952; Trotter & Gleser, 1958<sup>a</sup>; Trotter & Gleser, 1958<sup>b</sup>; Clarisa Watson Jiménez, 2019; Velasco, 2018; Pardini, sd), the study of occupational markers (Capasso et al., 1999; Mariotti et al., 2007; Mariotti et al., 2004) and the study of health conditions (Ortner, 2003; Aufderheide & Martin, 2006). In the case of the Boccolari-Parenti collection, these analyses have been supplemented by the most modern paleoradiological, archaeobotanical and laboratory approaches currently available (Traversari, 2021; Traversari, 2019). The methodological approach used for the mummy study necessarily

had to consider the problems and limitations required due to the state of preservation, the completeness of the body, and its fragility. By virtue of these peculiarities, in order to investigate the biological profile, the occupational aspects, and the pathological evidence, in addition to the usual direct investigation, it was necessary to proceed with paleoradiological investigations conducted at the “Azienda Ospedaliero - Universitaria Policlinico” in Modena. A total body computed tomography (CT) scan was performed with the following acquisition instrumental parameters: helical scanning, 2.5mm slice thickness with a reconstruction range of 0.7mm, 120kV, and 250mA, subsequently evaluated at the Diagnostic Imaging Department of the Morgagni-Pierantoni hospital in Forlì. A small sample from the mummy, a fragment of rib taken directly from its natural anatomical location, underwent radiocarbon dating using the high-resolution mass spectrometry technique (AMS) at the Center for Dating and Diagnostics (CEDAD) at the University of Salento. The obtained dating, calibrated in calendar age using the OxCal Ver. 3.10 software based on atmospheric data from INTCAL20. The hair from both the skulls and the mummy underwent direct entomological investigations. Regarding technical and diagnostic investigations, the following optical techniques were employed: Fourier Transform Infrared Spectroscopy (FTIR) and Raman spectroscopy. FTIR is an analytical method used in material characterization to understand the structure of individual molecules and the composition of molecular mixtures. On the other hand, Raman spectroscopy derives its name from *the Raman effect*—a specific phenomenon of light scattering observed in liquids, first documented by the Indian physicist Chandrasekhara Venkata Raman (1888–1970). The purpose of these analyses is to evaluate, through scientific techniques, the molecular structure of microsamples that were collected during the direct investigation of the skulls and the mummy. This allows for an intimate understanding of their chemical and physical characterization. These analyses have enabled the assessment of the preservation level of the mummified skin and other biological tissues compared to their state within living organisms. To complete the observations of the tissue ultrastructure of the mummy, some samples were evaluated using Environmental

Scanning Electron Microscope (ESEM) and Energy Dispersive X-ray Analysis (EDX) for microanalysis. This method allows us to work in a low-vacuum environment, observing the sample exactly as it was collected by utilizing secondary electrons that allow us to describe its morphology and backscattered electrons that provide information about its composition.

The collection consists of seven skulls, a calvarium accompanied by a mandible and a mummy; moreover, some skulls are associated with some cervical vertebrae and some textiles. Apart from one skull, the other seven appear skeletonized with large chunks of mummified skin, scalp, and hair. The mummy, as the term itself suggests, preserves considerable pieces of soft tissue, and still maintains the posture given to the body during burial, which must have been prefigured as a classic fardo. The diagnosis of sex, as well as the other aspects characterizing the biological profile of individuals, has been affected by the degree of individual representation of the remains. However, the discriminating indicators observed allow us to arrive at some interesting evaluations. The anthropological sample comprises six adult and three subadult individuals (two children and one infant).

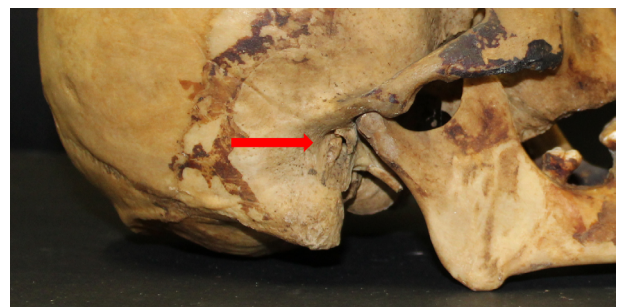
## Discussion

### *Skull analysis*

Considering the level of skeletonization reached by the seven skulls and the single calvarium, the investigation applied was the direct analysis. Two individuals are certainly attributable to the female sex, four to the male sex, and, while for the sub-adults, given their young age, the sexual dimorphic characteristics have not yet been expressed, it has not been possible to advance reliable sex diagnoses except to formulate hypotheses, pending a definitive genetic diagnosis. This phase made it possible to detect, in the first instance, the presence in most of the individuals – in six cases out of eight – of some characters defined as discontinuous non-metric, which may imply a certain genetic relationship or in any case a biological affinity between individuals of the same population. The most recurrent characters are defined as sutural ossicles or fontanellars, supernumerary accessory ossicles that form along the

sutures of the skull, and do not cause any disturbance to the living individual. Interesting considerations can be obtained from the study of muscle activity, a mirror of the occupational activities that the individual has sustained in life, through the analysis of the insertions of muscles and tendons on the bones, called entheses or enthesopathies, especially in the presence of inflammatory alterations. These investigations can be combined with detecting some non-metrical characters, although in this case they are strongly limited by the availability of the sole skull per individual. These analyses have shown in some male individuals (Id. 1, 2, 4, and 5) rather intense stress of the masseter muscle, responsible for the masticatory action which, in our case, may have been engaged in a continuous and routine manner to chop or soften foods and vegetables. Interesting is the presence of auricular exostosis in a male individual (Id. 4), a condition that develops mainly due to environmental factors. One of the leading causes is prolonged exposure to water and cold wind; in particular, repeated immersion in cold water seems to trigger a protective response of the body, which produces excessive amounts of bone to protect the external ear canal. Nowadays, it is a typical condition to which swimmers and surfers are exposed; in the case of ancient populations, as in our case study, the presence of this character is probably attributable to the action of spearfishing (Figure 1).

In at least three individuals (Id. 1, 2, and 5), all male, an evident deviation of the nasal septum was observed, which, considering the level of deviation from the body axis and the depth of the affected bone portion, could be traced back to traumatic rather than congenital events. It is, therefore, plausible to hypothesize



**Figure 1.** Id. 4, the red arrow indicates a case of external ear exostosis.

that these three individuals may have suffered from rhinitis and inflammatory processes in the upper airways caused by congestion and accumulation of mucus that stagnates within the nasal choanae and in the paranasal sinuses. The presence only on infants Id. 7 and 8 of diffuse *cribra orbitalia*, pitting of cortical tissue, appears to be relevant, which is, among other things, attributable to a disorder of the hematopoietic system caused by persistent anemic conditions, triggered in the case of subadult individuals by a nutritional deficiency (Yoga Pratiwi, 2021). Anemia generally causes a lowering of hemoglobin levels, therefore oxygen, while increasing the production of erythropoietin, hormonal products of the kidney, which increase the production and maturation of red blood cells (Walker et al., 2009). If this hormonal process is inadequate and negatively unbalanced with respect to the restoration of homeostasis, the bone marrow triggers a reparative response, increasing the production of red blood cells and causing a thickening of the diploic tissue at the expense of the cortical one (Wang, 2023). These anemias arise due to a chronic deficiency of vitamins B12 (cobalamin) and B9 (folic acid), which are taken up by the body mainly through meat consumption. For this reason, they can be triggered by a diet deficient in these foods, associated with pathologies that do not allow adequate absorption of nutrients such as gastroenteritis and diarrhea (Figure 2).

At the level of the masticatory system, numerous cases of periodontal disease are widely observed, such as inflammation of the periodontal tissues, which in life may have led to a loss of the attachment system of the teeth with respect to the alveolus, with consequent formation of periodontal pockets, tooth mobility,

gingival bleeding, abscesses, and suppurations, up to the loss of the dental element. In the specific cases of Id. 2 and 4, there are widespread cases of rather extensive and deep periapical abscesses, Id. 1, 3, and 4 have widespread periodontal diseases that have led to the loss of some *intra vitam* teeth of the individual, with consequent alveolar retraction. Peculiar is the case of the male individual Id. 4, who has lost all the dental elements of the mandible at life, while preserving the maxilla teeth. There are also some cases of complete resorption of the alveolus, testifying to events that occurred long before death. The dentitions observed also show widespread tartar deposits and some cases of occlusal and cervical caries, a reflection of a diet rich in carbohydrates and an insufficient hygiene routine.

#### *The study of the mummy*

The results of the tomographic analyses confirmed the diagnosis of the female sex already assumed by the direct investigation. Moreover, it was possible to establish that she was a young adult with an age at death of 17-20 years, whose height at life was around 139cm, with a general average index of robustness and good bone density. The radiological investigation also showed that the first four cervical vertebrae are absent, probably removed or fallen through a laceration on the neck, perhaps during the movements that the mummy underwent in ancient times. Some teeth have been found in the abdomen and laryngeal area. Inside the rib cage, it was possible to identify the trachea with the tracheal bifurcation, posteriorly and still in place the esophagus, the mediastinal pleura, and most of the diaphragmatic



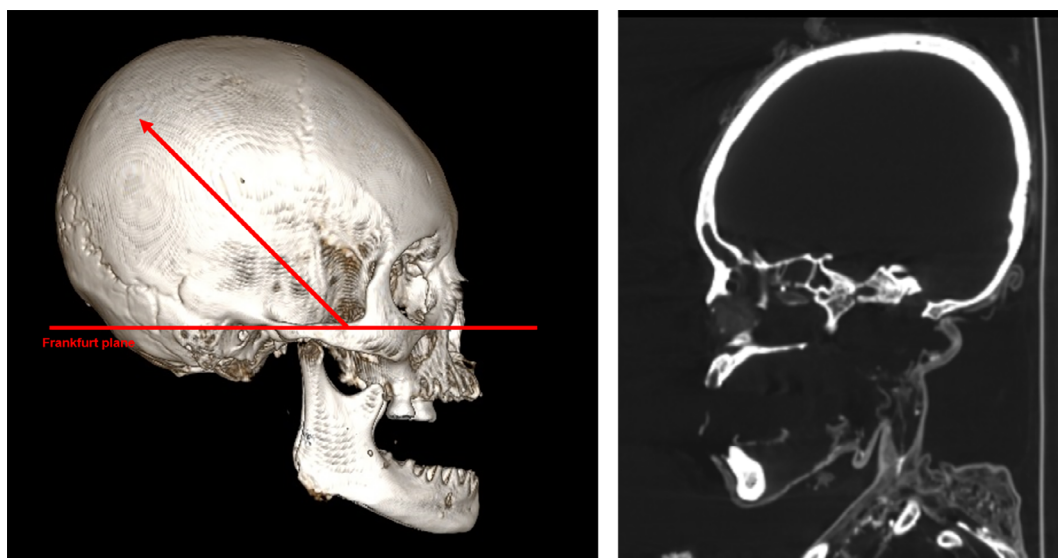
**Figure 2.** on the left Id. 7, on the right Id. 8, in both cases, the roof of the orbit is affected by *cribra orbitalia*.

muscle. In the abdomen, two symmetrical posterior formations have been observed, which could be related to the kidneys. Additionally, a tubular structure that bifurcates and gives rise to other small tubular structures has been identified, suggestive of the abdominal aorta with iliac arteries and superior mesenteric artery, as well as the celiac tripod. Tubular structures have also been identified in the thigh, possibly mummified remnants of common femoral arteries with bifurcation into superficial and deep femoral arteries. The direct investigation, in conjunction with radiological evidence, has further revealed an abundance of skin, often arranged in folds, in certain anatomical regions, indicating a non-slender build for the girl in life. No pathological conditions of any kind were identified. Within the diagnostic limits of the CT scan and inspection, it can be inferred that the girl could have been in good health, and her overall nutritional state was good, given the absence of evident deficiency lesions at the skeletal level. A curious, yet not uncommon aspect during the study of natural mummies has been provided by the recovery of several seeds of *Gossypium Barbadosense*, an angiosperm plant belonging to the Malvaceae family and native to South America (now known as Peruvian Pima cotton) from the abdominal cavity. This presence within the abdomen is most likely attributable to the activities of burrowing rodents that created nests in safe and

protected places, even if seemingly unusual, as in our case (Traversari, 2023). Radiocarbon dating yielded a range of 1287-1409 AD with a 95.4% probability. This timeframe corresponds to the Late Intermediate Period of the Chancay Culture, during which the young girl and perhaps even the eight skulls lived.

#### *Intentional deformation of the skull*

The craniometric study conducted on the entire Boccolari-Parenti collection, using direct methods for the eight skulls and virtual techniques for the mummy, clearly showed that some of these ancient inhabitants of Ancona underwent intentional cranial modification. The craniometric index values obtained, when compared with data from a series of deformed skulls from the same necropolis (Pardini, sd), can be attributed to a modest oblique tabular deformation. The cranial indicators obtained reveal a general brachycephalic index (a skull with a decreased antero-posterior diameter). Additionally, in the case of Id. 1, 5, 6, and the mummified girl, a hyperbrachycephalic index is observed. This hyperbrachycephalic index is characterized by pronounced flattening of the occipital region, where the superior nuchal line and the inion, instead of being located inferiorly to the Frankfurt plane, surpass it by positioning themselves above it (Figure 3).



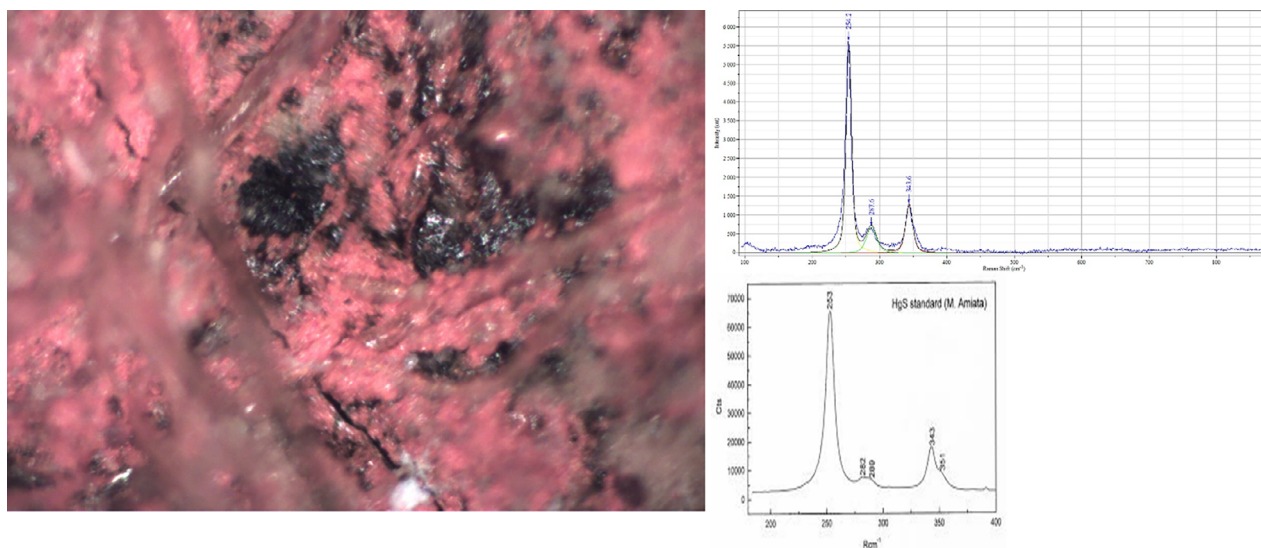
**Figure 3.** On the left a 3D rendering from CT data in a lateral view. The red line represents the Frankfurt plane, while the arrow highlights the direction in which the intentional cranial deformation developed. On the right, there is a sagittal CT view of the mummy's skull.

The intermediate facial index (mesene), high orbits (ipsiconchia), and narrow nasal aperture (leptorhinia) are associated with strong tensions induced by cranial deformation. The oblique tabular deformation was achieved by applying tight bandages to the frontal region and using tablets or rigid supports in the occipital area of the infant's skull. The purpose of this deformation was not solely aesthetic; it aimed to represent a distinguishing feature of individuals belonging to selected population groups.

### *Instrumental investigations*

Entomological investigations revealed that very few insects had colonized the finds, primarily moths that likely settled after the bodies were mummified. Additionally, the presence of an endemic beetle from the Po region and lice eggs was recorded found only on Id. 3. Excluding the lice eggs, which are typically associated with *in vivo* stages, it is evident that this minimal insect presence on the bodies—some of which were not even originally located in the primary burial region—supports the hypothesis that both the mummy and the skulls were preserved within funerary bundles, thus protected from natural insect proximity

to the remains. Only hypothetically, after their extraction, they become accessible. The results of FTIR and Raman spectroscopy provide valuable information regarding any embalming preparations that may have been used, the materials employed in this practice, or indications that suggest whether the body underwent natural mummification. The spectra of three samples of endocranial meninges extracted from Id. 5, Id. 7, and Id. 8, respectively, indicate that these three finds are in similar preservation conditions. The proteins within the tissue appear to be well-conserved and similar. However, some differences can be observed in the spectra, particularly with greater similarity between the samples from Id. 5 and Id. 7 compared to Id. 8, which appears more degraded. Additionally, a fragment of epidermis taken from the cheek of Id. 5 revealed the presence of a red pigment, characterized by a granular consistency with darkening in certain areas. The properties of this red substance, investigated using Raman spectroscopy, were compared to a standard spectrum of cinnabar (Mercury Sulfide - HgS). The investigated substance exhibited spectral characteristics consistent with the reference spectrum of cinnabar, a result also obtained from the sample from Id. 7 (Figure 4).

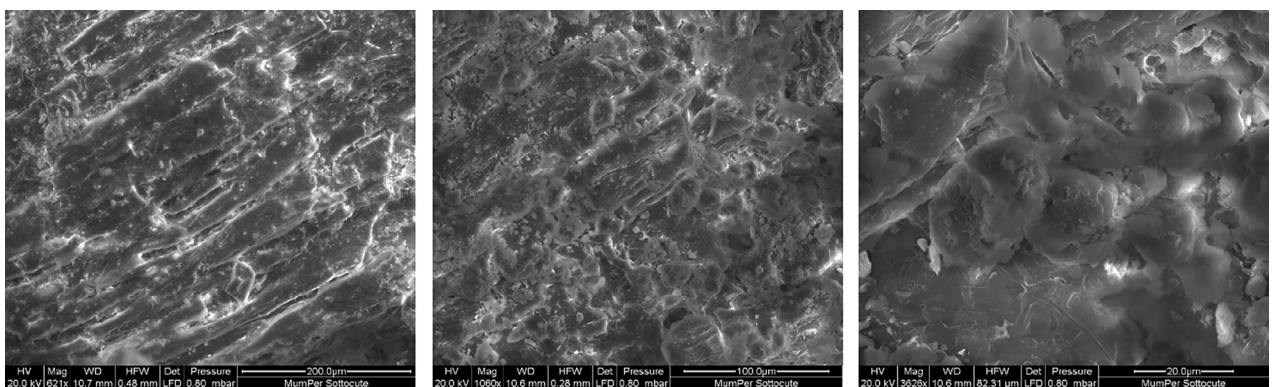


**Figure 4.** On the left, a 10x magnification of the skin fragment taken from the cheek of Id. 5 reveals evident traces of darkening. In the upper right corner, the Raman spectroscopy of the same fragment is compared to a standard spectrum of cinnabar, mercury sulfide (HgS) (lower right corner). The investigated substance exhibits spectral characteristics consistent with the reference spectrum of Cinnabar.

Mercury sulphide, of mineral origin, is intensely red in color. The points where darkening occurs have been observed and investigated in other contexts as well, and their interpretation remains an open question. In some cases, their presence has been explained as a structural transition from cinnabar (pyramidal HgS) to metacinnabar (cubic HgS). However, the most plausible hypothesis, especially considering the archaeological context of the artifact in question, attributes the formation of these darkening patches to degradation phenomena of cinnabar. These processes lead to irreversible darkening, such as the formation of surface colloidal mercury or the cleavage of cinnabar into Hg (0) and S (0). The observed alterations may have been caused by the preservation environment. The FTIR spectrum of the analysed skin fragment also indicates the presence of the pigment. It is conceivable that the pigment was applied after death for ritualistic purposes, as noted by Vreeland in their study of pre-Columbian mummies from Peru (Cockburn et al., 1998; Bongers et al., 2023). Furthermore, the skin spectrum of the mummified girl revealed multiple peaks due to the various molecular and macromolecular components typically found in the dermis: lipids, proteins, water, and carbohydrates. Numerous absorptions detected are attributed to an increased quantity of acids, suggesting the initial formation of adipocere, a process subsequently halted due to body desiccation. The observed IR bands also highlight molecular traces of glycans, polysaccharides that, along with proteins,

form glycoproteins. Generally, the number and size of glycans dramatically decrease after an individual's death due to microbial attack. In mummies, the process is halted, and the produced glycosylation protects the protein skeleton of collagen, thereby promoting the integrity of the mummified cutaneous tissue. The results obtained from the amide band analysis are closely linked to the formation of an intense band in this spectral region, as they indicate significant damage to the collagen structure within the tissue. The final result suggests that mummification was natural and not due to embalming processes. ESEM and EDX technology has confirmed natural mummification, with a reasonable degree of tissue structure preservation. Residues from the burial environment and some more recent fungal colonization are evident. Specifically, the muscular structures and the reticular dermis are well-defined. The dermis appears rich in collagen fibers, with a consistent and abundant presence of dispersed adipocytes, supporting the observation of a non-slender build, as previously noted (Figure 5).

Regarding microanalysis, the obtained spectra allowed for the identification of silicates, which are indicative of soil contamination, as well as the presence of calcium carbonate. Numerous microscopic particles were also detected, along with traces of iron and sulfates, which are commonly found in muscle tissue. Finally, the presence of interwoven structures resembling fungal hyphae, often encountered in museum finds of this kind, was also identified.



**Figure 5.** On the left, it is possible to observe the reticular dermis, which appears distinct and rich in collagen fibers. In the center, there is the abundant adipose tissue. On the right, there is a magnified detail of the previous image, where some adipocytes are visible.

## Conclusion

By utilizing modern research methods, the examination of ancient anthropological collections can lead us towards a fresh perspective. In the instance of the Boccolari-Parenti collection, this new methodology has enabled us to accurately determine the date of the anthropological collection, which was previously thought to be different. The research conducted was able to confirm the presence of cinnabar pigments on certain skulls, which had only been speculated through historical sources. Additionally, the study provided a thorough analysis of the extent of tissue preservation and identified any parasitic colonization that was caused by improper preservation techniques. A paleoradiological study was conducted on a mummy, which helped to assess the preservation level of its internal organs. Additionally, the study identified a degree of intentional cranial deformation, which had also been previously observed on some of the skulls in the collection. To conclude, it is essential to reconsider anthropological museum collections and conduct new analyses with the latest technologies and tools available today. This approach serves a cognitive purpose and highlights the importance of museums as vital custodians of valuable biological archives. These archives are ready to provide new and interesting results, making museums an essential resource for researchers and the public alike.

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